each side supersedes the five or six small sharp spines of that species. The edges of the terminal spine are serrated.

Astacus lævisculus, Dana.

Columbia River, Puget Sound.

San Francisco, Aug. 28, 1878.

XXXVI.—*On the probable Nature of the Animal which produced the* Stromatoporidæ, *traced through* Hydractinia, Millepora alcicornis, *and* Caunopora, *to* Stromatopora. By H. J. Carter, F.R.S. &c.

As there are undoubtedly several species of *Stromatopora*, and each species may have several varieties, while the whole may be variously altered by mineralization, these contingencies are too numerous for me to undertake the palæontology of the whole group, and therefore I shall confine myself solely to the probable nature of the animal which produced them.

I need hardly premise that in proportion to the knowledge of beings actually living will be that of those which have passed away—that is, that it is impossible to be a good palæontologist without being a good morphologist, either specially or generally, and therefore that a knowledge of geology alone cannot make a good palæontologist.

Take, for instance, the following fact, which no amount of fossil material could afford, and which nothing but a knowledge of recent structure could supply, and the foregoing premise becomes evident.

Thus, the embryo of *Hydractinia echinata* begins its structure, both soft and hard, by developing a sarcodic membrane which is traversed by a vascularity consisting of *rami*, *ramusculi*, *ramuscunculi*, &c., *over* which minute points of chitinous or horny matter subsequently appear along the course of the vessels (that is, outside their walls), which, after having grown into branched elements, ultimately become incorporated in the formation of the fibre of the polypary or cœnenchyma, after the manner of *Millepora alcicornis*, as will be more particularly explained by-and-by ('Annals,' 1873, vol. xi., and 1877, vol. xix.). When the soft parts are abstracted the *spaces* alone which they occupied are left, whereby the cœnenchyma becomes, as it were, the *mould* of the vessels. *Pari passu* with the development of the cœnenchyma is that of the polypites and the development of new vascular *foci*, from which it happens

that the ultimate radicles of the branches of the different *foci* unite with each other, and thus the structure is extended.

This, which may be termed the "proliferous membrane," hydrophyton of Allman, or cœnosarc, may be assumed to have existed in all Hydrozoic cœnenchymata of the kind, whether present or past; and thus our knowledge of the recent structure will be found to afford us decisive explanation of that which might otherwise have remained conjectural for an unlimited period.

Passing on to *Millepora alcicornis*, which is a Hydrozoic coral, we find precisely the same kind of grooved venation, indicative of the previous existence of a "proliferous membrane," as in *Hydractinia echinata*, only that, for the most part, it is concealed by the surface-layer, which requires to be picked off with a sharp-pointed instrument to bring the venation into view. (Scraping off the layer with a sharp knife will also do this, but not so satisfactorily, especially as by the former method portions of the dried vessels themselves often remain *in situ*.) Yet occasionally the grooved venation appears in the surface, as may be seen on a specimen at the British Museum in one of the upright cases in the coral-room, labelled accordingly. (This specimen is composed of cylindrical anastomosing branches beset with short, stout, spine-like processes, altogether presenting a flat clathrous mass about twelve inches broad and nine inches high as it now stands.) There is also another specimen, more like the typical *Millepora alcicornis* in shape, from the flatness of its branches, whereon the grooved venation is partial—that is, obvious outside in some parts only. This venation was seen by Mr. H. N. Moseley "on the surface of a corallum in a species of *Millepora* obtained at Zamboangan, Philippines" (Phil. Trans. 1877, vol. clxvii. p. 125); and a similar reticulation may be observed with a common lens *in* the horizontal lamina of *Tubipora musica*, as it appears through the upper layer.

In a vertical fracture of a branch of *Millepora alcicornis*, holes here and there, indicative of the larger branches of the grooved venation, may be seen just under the surface-layer, while the smaller ones which rise into it are lost by becoming continuous with the vermicular interspaces of the cœnenchyma; except in some instances, where the vessels which occupy them appear to have become calcified and thus rendered visible by a slight portion of the surface-layer being shaven off with a very sharp knife. Indeed the same condition sometimes leads to their permanency on the *outside* of the surface-layer, where they may be seen with the naked eye, or at least with a lens of moderate power. At the same time,

in this state they must not be confounded with that common calcareous white mycelium which, either Foraminiferous or Saprolegnious, pervades almost every marine calcareous structure.

That, however, the vessels of the "proliferous membrane" are sometimes calcified is worth remembering, as it may hereafter explain how, in the fossil species, they appear sometimes as *mere spaces*, whereby they may often be easily overlooked, and at others in the form of *calcified canals*.

The vascularity of the "proliferous membrane," which has been examined by Mr. Moseley in the recent state, and identified with the "hydrophyton" of Allman (cœnosarc auct.), is beautifully represented in his figures 12 and 16, plate iii. (*op. et loc. cit.*), where the vessels are shown to be surrounded and filled respectively with ectodermic and endodermic cells of different kinds which produce the various elements of which the Millepore is composed.

Having thus pointed out the source from which the coral-lum of *Millepora alcicornis* is derived, I have now briefly to allude to the composition of its ultimate structure; and for this purpose let us assume that a branch has been broken off from the main specimen, and that we are examining the vertical fracture (for this is preferable to any other method, as involving the least destruction of the more delicate parts). We may observe that the branch is marked by an axial, a middle, and a superficial structure, all three of which are differentiated by the following peculiarities. The "axial structure" is here represented by a number of minute holes in juxtaposition (that is, a cribriform cœnenchyma), in which the surface of the hard parts towards the holes or spaces is more compact than the rest; that is, the surface is more opaque and whiter than the interior, which, on the other hand, is composed of more transparent calcite. This, again, which will be generally found to be the case with the cœnenchyma, is worth remembering, because it will lead to the explanation of a similar appearance in the elements of the fossil structure, which otherwise might be set down as originally hollow or filled with cœnosarc. The "middle structure," on the other hand, is more compact, and its cœnenchyma composed of a *curvilinear* element or fibre, moulded over a vermiculo-reticulate cœnosarc, whose tortuous anastomosing canals alone remain in the dried corallum, more or less obliterated *here* by thickening. This basic structure, again, is traversed by tubular *spaces* at variable distances from each other, which radiate from the "axial structure" towards the circumference of the branch ('Annals,' 1878, vol. i. pl. xvii. fig. 5), where they end in the

calicles respectively, and, besides being in direct communication with the vermicular spaces of the *curvilinear* cœnenchyma, which open into them all round, are more or less divided *transversely* into compartments by calcareous septa (often surmounted by a stylous process), which have been called "tabulæ," each compartment indicating the successive development of a polypite or hydranth; hence the term "tabulated" has been applied to them. (This is a common feature of the tubes of *Heliolites*, *Halysites*, and *Favosites*.) Lastly, the "superficial structure," which is the surface-layer, is formed exactly like the "middle structure," only that, being actually under growth, it is less compact, whereby the transverse sections of the larger branches of the "proliferous membrane," or hydrophyton, are rendered more visible between it and the outer margin of the "middle structure" than in the layers of the latter.

Turning now to an examination of the branch *longitudinally*, we may reverse the order of the description; and taking the "superficial structure" first, we observe the same curvilinear character of the elementary composition of the cœnenchyma as before mentioned, but more open and, where definitively formed, presenting, sometimes on the surface and generally in the deeper parts, a convoluted appearance of the typical curvilinear character, in miniature like the convolutions of the brain, united by transverse processes or bars—in short, very much like the remains of a thoroughly worm-eaten piece of wood,—but where imperfectly formed, as on the surface chiefly, more or less spined, owing to its being formed in the first place of small, nodose, bacillar, and branched (?) calcareous spicules, which, before they become entirely incorporated into fibre, project more or less beyond the surface of the latter (accounting, perhaps, for the granular and cribriform appearance of the fibre in *Caunopora* &c., that will hereafter be mentioned), subsequently passing into the typical *curvilinear* form, and finally, more internally (that is, in the "middle structure"), into a solid crystalline state with radiated structure, like that represented by Mr. Moseley (*op. et loc. cit.* pl. 2. fig. 8), in which no trace of the original spicular element remains, as in *Tubipora musica*—a transition first mentioned by Ellis in the red coral (*Corallium rubrum*), who states that he received the "hint" from Dr. Donati (Ellis and Solander, 'Nat. Hist. of Zoophytes,' 1786, p. 78).

This can be well seen in *Millepora alcicornis* with an inch-focus compound power, magnifying about 100 diameters, probably better in the living than in the dried specimen, where, unless protected by the overgrowth of a piece of

sponge, as is often the case in specimens from the West Indies, it is generally rubbed off like the corresponding parts in *Tubipora musica*. The process of incorporating the spicular elements into calcareous fibre seems analogous to that which takes place in the vitreous hexactinellid sponges, wherein the mould of the spicule may be brought back by some solvent, viz. an acid in the former and an alkali (as Mr. Sollas has shown) in the latter. In *Corallium rubrum* a transverse section ground down to extreme thinness will well show what was stated by Donati so long ago.

Here and there again, on the surface of the "superficial structure," may be seen the calicular spaces of the full-formed polypite and those of the zooid respectively, more or less irregularly scattered about, more or less thickly, more or less in number, the one or the other, sometimes in groups, as in the species from Tahiti figured by Mr. Moseley, of which I also possess a specimen from the West Indies.

Occasionally, as before stated, the surface of the "superficial structure" presents the grooved venation indicative of the vascularity of the "proliferous membrane;" while for the most part this only becomes visible after the surface-layer has been picked off, as before stated, when it may be seen sunk into the outer layer of the "middle structure."

Splitting now the branch longitudinally, both the "middle" and the "axial structure" are brought into view, when the former, of course, presents the same features as in the transverse fracture; while the "axial," which in the transverse fracture only appears as a cribriform surface, is now found to be composed of *longitudinal* tubes in juxtaposition, more or less interrupted by *tabulæ*, and more or less pierced with holes, by which they communicate with each other.

In most instances also, as before stated, the grooved venation, which represents the larger vessels of the "proliferous membrane" or hydrophyton, is concealed beneath the superficial layer; but as the branch grows by additional layers to its surface, it is evident that this layer must be thin before it can be thick, and that therefore, if the specimen meet with its death or be seen when the surface-layer is thin, the vascularity will be visible to the naked eye, and *vice versâ*. Hence the absence of the grooved venation on the surface in some, but not in all, specimens may receive this explanation both in the recent and in the fossilized structures.

This seems to be the proper place to notice the differences that exist between a coral (Actinozoic or Hydrozoic) and a sponge, which may be thus described, viz.:—

A coral grows from an embryo which develops one animal,

the polyp; and this animal has but one opening, through which the food is taken in and the refuse discharged. After this a plurality of polyps are developed from stoloniferous buds around the original one, in the form of a layer supported by their calcareous cœnenchyma, the original polyp developing another polyp *directly over* itself; then other layers of polyps accompanied by their cœnenchyma follow, until the ultimate form of the coral, whether branched or massive, is attained; while as each layer of polyps is formed respectively over its predecessor (increased by *branching*, of course, to fill up the extending circumference) the parts below pass into cœnosarc, which thus, for a time, fills up the interspaces of the cœnenchyma, until, in the massive corals, the cœnosarc itself perishes, and thus the base becomes virtually dead. In *Madrepora abrotanoides* the successive development of the central or original polyps over each other is distinctly shown by a branch which is broken off at each end, when the centre of the cœnenchyma at both extremities presents the septate or mesentericated cell of the polyp, with this difference only, that the structure is thicker or more condensed in the lower or older part. Still the mesentericated tube is continued throughout; and as the corallum of the Hydrozoa is subject to the same repetitionary conditions in development, it is not uncommon to see the same tube, whatever this may have been, continued vertically through the mass in a similar growth of *Stromatopora*, until it appears in the centre of the stelliform hydrophyton on the surface, presenting the same appearance over each successive layer of the coral. To this point I shall have to return by-and-by, merely observing now that what produces the polyp also produces the hydrophyton, and therefore the two may have been combined or separate in the same mass.

A sponge, on the other hand, grows from an embryo which develops a sarcoid surface-membrane pierced with holes (pores) which are ever opening and closing, and interiorly charged with hollow globular groups of mono-flagellated animals, viz. the spongozoa. These, again, receive their food through the pores, and discharge the refuse through the radicles of a branched excretory canal-system, which, becoming larger in proportion to the number of branches it receives, at length terminates in an expanded vent or osculc on the surface. *Pari passu* with this development, a skeletal structure is formed, which, for the most part, is kerato-siliceous or kerato-calcareous; that is, it is composed of chitinous or horny fibre strengthened by siliceous or calcareous spicules. After this, the structure goes on increasing in bulk until the

ultimate form of the sponge, whether branched or massive, is attained; but as this increase is only attended with a transformation of the old surface into the internal structure, and the groups of spongozoa go on increasing, while they do not die out in the interior, the excretory canal goes on increasing in size also, until of necessity (that is, from its importance) it becomes the most prominent feature in the structure of the sponge, agreeing in this matter with the excretory canals in all animals, which are largest and most dilated at their outlet —trumpet-shaped.

Hence to have a sponge without a distinct excretory canal-system which, from its preponderance over the other structures, can be seen with the naked eye, would be an impossibility; while the nature of a coral-animal requires nothing of the kind, since it is situated on the *surface* of the mass and discharges the refuse of its food through the same orifice by which it entered the body on the spot.

Having now considered the structure of these recent animals, let us turn our attention to that of the fossilized forms called *Stromatopora*. And here it is desirable to premise that they will be treated of under the family name of Stromatoporidæ, in which the genera *Stromatopora* and *Caunopora* will be included, and the latter described first, as it is partly through *Caunopora* that we shall have to ally *Stromatopora* to *Millepora alcicornis* and thus to *Hydractinia*.

In 1840 (Trans. Geol. Soc. Lond. vol. v. pt. 3) Lonsdale figured and described *Caunopora*, Phill., under the provisional name of *Coscinopora placenta*, observing that "other specimens [of *Caunopora*] might be mistaken for *Stromatopora concentrica*, except that *the tubes* [the italics are mine] with careful search may always be found."

In 1841 Phillips ('Palæozoic Fossils of Cornwall, Devon, and West Somerset') gave the name of "*Caunopora*" to this genus, again with reference to the "tubes;" while Baily, in 1876 ('Characteristic Brit. Fossils'), calls it *Stromatopora placenta*, Lonsdale, previously named by Rosen *Stromatopora Schmidtii* ('Ueber die Natur der Stromatoporen und über die Erhaltung der Hornfaser der Spongien im fossilen Zustande,' Dorpat, 1867, Taf. 4, 5). Finally it has been illustrated by Nicholson and Murie under the name of *Caunopora* (Linn. Soc. Journ., Zool. vol. xiv. p. 219, and pl. ii. fig. 4).

The necessity of making this a distinct genus of the Stromatoporidæ with a different name will hereafter appear evident; and as the latter has already been done, I shall allude to it under the name of *Caunopora* (Phill.) *placenta*, Lonsdale.

My observations on *Caunopora placenta* have been manifold; and up to my last communication on the subject I had always alluded to it under the name of "*Stromatopora*" ('Annals,' 1878, vol. ii. p. 85). This having been explained, then, let us proceed to a description of the fossil dissected out of a calcareous laminated amorphous mass from the Devonian Limestone, about two feet (and probably more originally) in diameter.

Here it is composed of large nodules growing from different nuclei and enveloping during its spreading course more or less foreign material and the petrified remains of many foreign organisms. Taking one of these nodules about three inches in diameter (for they vary in size above and below this measurement), we find it hemispherical or parabolical; and commencing with a horizontal section through the base, the central or axial part is observed to be composed of a cribriform structure, occasioned by the presence of a tubulated cœnenchyma, to be more particularly described presently, of which the ends of the tubes in juxtaposition are alone here visible; outside which, extending to the circumference, is a *curvilinear* cœnenchyma (that is, *curvilinear* in the element, as already described in *Millepora alcicornis*) through which *tubes* at a variable distance from each other radiate from the axial structure to the circumference, intermixed with rods of opaque white calcite taking the same direction, which are intimately connected with the *curvilinear* fibre of the cœnenchyma, of which they, indeed, form part; while they are composed of a more transparent calcite internally, which would lead to the supposition that they were once hollow, did not the same differentiation appear in the cœnenchymal tissue between the tubes in the "axial structure" of the living *Millepora alcicornis*, as before stated. Further, these radiating separated tubes are more or less divided into compartments by *tabulæ*; and here and there, along the lines of concentric laminæ which they traverse, and which characterize the structure generally, are seen circular spaces indicative of vertical sections of horizontal vessels, which we shall presently find, by the indications of the previous existence of stelliform groups of the hydrophyton-vessels on the surface, to have existed between the laminæ respectively.

If we now make a vertical section through the axis of the cone, the same structure will of course present itself externally, while the axial structure, consisting of tubes in juxtaposition radiating upwards and outwards, will come into view *longitudinally*, when they will be found to have been so numerously perforated with holes and traversed by *tabulæ*, that, at first, I was inclined to think this specimen of *Caunopora* had grown

upon *Favosites gothlandicus*; nor was I convinced to the contrary until I found a similar differentiation in *Millepora alcicornis*, as already stated, viz. in the "axial structure."

Lastly, if we go to the surface of the nodule or cone, we shall find it to present the same *curvilinear-fibred* cœnenchyma with the separated tubes and rods as above described; but instead of a longitudinal view of them we have here only their ends, in which the former often present a white opacity in the centre as if some of the *tabulæ* had possessed a styloid point similar to that seen on some of the *tabulæ* in *Millepora alcicornis* (at all events there was something of the kind here); while the rods present a transparent centre within the opaque white calcite externally, corresponding to what was seen in the longitudinal section of this part of the cœnenchyma in the horizontal section of the base. But the most remarkable feature of the surface is the presence of more or less stelliform groups of lapidified vessels or spaces irregularly scattered over the laminæ *horizontally*, and therefore repeated after this fashion throughout the mass. The rays of these stelliform groups are more or less dendritic in their form, being branched and subdivided repeatedly, until their ultimate divisions are lost in the vermicular spaces of the cœnenchyma, now equally lapidified, thus becoming continuous with the branches of the neighbouring groups. It is desirable to remember this feature, as we shall hereafter find it to be repeated in *Stromatopora*, sometimes as mere spaces, sometimes as calcified tubes.

In some species of *Caunopora* the *curvilinear* fibre, always more or less granular, appears to be cribriform; but if originally composed of an aggregation of minute spicules, as in *Millepora alcicornis*, this appearance is easily explicable. It is, however, not confined to *Caunopora*; for the *curvilinear* fibre of other coralla (ex gr. *Battersbya inæqualis*) presents the same kind of appearance under similar circumstances—that is, when the plane of section has so passed through it as to show *its interior*; otherwise, as by looking at the fibre *below the surface* of the section, we may observe that the lamina which has enclosed the spicules to form the fibre presents nothing of the kind or merely a granulated exterior.

Thus the presence of spicules in the fibre of *Stellispongia variabilis* ('Annals,' 1878, vol. i. pl. xvii. fig. 10), seen in a microscopic preparation kindly sent me by Dr. G. Steinman, further strengthens me in my opinion that it also was a Hydrozoic coral, at the same time that it points out how easily such fossil structure might be confounded with that of sponges. One should always remember that Nature is ever imitating

herself, in general forms especially, and therefore that like forms are not always accompanied by like functions.

What the surface of *Caunopora* was like in its original state I do not know, as all the specimens that I have seen are too weathered to describe this satisfactorily. Perhaps it was like that of *Parkeria*, whose structure elementarily very much resembles that of *Caunopora*; that is, the surface consisted of gentle elevations more or less irregular in their form and diameter. But internally the tubes are often united by cross branches, similar to *Syringopora* in this respect, although widely different otherwise, as the tubes of *Caunopora* are united by the *curvilinear* cœnenchyma, while *Syringopora*, like *Tubipora musica*, had *nothing* between its tubes. Again, a branch of the "stelliform" groups of vessels is often connected with one of these calicular tubes, showing that the calicle and vessels may be combined, and developed from each other, as the case may be.

All this has been witnessed in the Milleporidæ by Mr. Moseley, who states (*op. et loc. cit.*) that "the thin incrusting films of *Millepora*, when dead and dry, show well the ramifications of the canal-systems and their connexion with the calicles" (p. 120), and "in some cases large tertiary branches of the canals join the zooid-cavities directly" (p. 125).

Thus in all essential points the structure of *Caunopora placenta* was the same as that of *Millepora alcicornis*; only the large-branched vascularity of the "proliferous membrane," or hydrophyton, instead of straggling over the surface, was developed from more *foci*, and thus brought into more stelliform shapes. Even in the Stromatoporidæ this differs in degree, as may be seen by comparing Baron Rosen's lithograph of his *Stromatopora elegans* (Taf. iii. fig. 1) with that of *S. Schmidtii* (Taf. iv. fig. 1, *op. cit.*), which, as before stated, was probably a *Caunopora*); while in the specimen of *Stromatopora mammillata*, Nich., from which fig. 10, pl. 1 (Linn. Soc. Journ. *l. c.*) was taken, which came from Canada West, and was shown me by Dr. Murie, *both* the straggling and stellate forms of the vascularity are present on the *same surface*.

We now come to *S. concentrica*, Goldf.; but who has defined this species? Certainly not Goldfuss, either in his diagnosis or in his illustration. Thus, when authors speak of *S. concentrica*, I, after having now studied the Silurian and Devonian species probably as extensively as any one living, whereby a repetition of the same forms in every collection, both English and American, has been witnessed, am thus inclined to think that I have seen specimens of the greater part of the species; yet I am at a loss how to define *S. concentrica*,

Goldf., further than Lonsdale has done by stating that it does not present "tubes" like those of his "*Coscinopora placenta*," = our *Caunopora placenta*—which is totally inadequate to our present purpose. There are, however, other features which are common to many forms of *Stromatopora*-structure, which I have never seen in *Caunopora*; and if we combine these with the absence of the "tubes" and a more or less gnarly structure (like that seen in knotty wood) in the section, already represented by Phillips (*op. cit.*) in his figure of *S. concentrica*, we might then get a typical form to which we might still apply the name given to it by Goldfuss, and then know what we were writing about. To these "other features" I shall now allude.

The "gnarly" or undulating character in the general structure of *Stromatopora*, where the bend of the undulation may vary from a few lines to as many inches in diameter more or less, should not be confounded with the *curvilinear fibre* of the cœnenchyma in *Caunopora* already described, nor with the *rectilinear fibre* of *Stromatopora* about to be mentioned. The term "*curvilinear*" has already been explained; and that of "*rectilinear*" means that the lines representing the elementary part or fibre of the cœnenchyma are all more or less straight.

As with *Caunopora*, so with *Stromatopora*; my observations have been manifold; but not having had the opportunity of dissecting a large block of the latter, as with the former, they have been made on fragments of weathered or unpolished and polished specimens respectively, the largest not exceeding nine by four and a half inches in diameter.

Looking at the *vertical* section of *Stromatopora concentrica*, Goldf., as presenting the typical structure of the family, the cœnenchyma may be observed to consist of more or less straight lines arranged horizontally, cut at right angles by vertical ones or rods, which are the thickest of the two; while the *horizontal* section presents a number of white points, which are the ends of the "rods," united together by a *rectilinear* structure consisting of straight lines, which extend between the points and between each other, so as to produce a cribriform lamina with triangular or multiangular spaces. For the term "rectilinear" I have hitherto used that of "hexactinellid," which was evidently a misnomer. Further it should be remembered that in some specimens or species the cœnenchymal structure is extremely fine, and in others, especially the rods, comparatively coarse.

Now, as the *vertical* section shows no trace of the structure seen in the *horizontal* one, saving the margin of the lamina,

which is represented by the horizontal lines of the former, and the vertical rods (which are represented by their ends only in the latter), respectively, while, where the plane of the horizontal section passes between two laminæ, the points of the rods *alone* are seen on the immediate *surface*, it becomes evident that the cœnenchyma is formed of vertical rods which support, at variable distances, the horizontal cribriform laminæ.

Again, it is evident that the cœnosarc of this cœnenchyma in *Stromatopora* was as continuous throughout as in that of *Caunopora*, and that the continuity through the cribriform laminæ was kept up in the same way as through the cribriform transverse septa of *Tubipora musica*.

Further, it may be observed that the white or opaque "rods" of calcite, as well as the rectilinear structure of the laminæ generally, present a more or less transparent calcite internally, as in the "axial structure" of *Millepora alcicornis* and in the rods of *Caunopora*, before noticed, whereby, if this had not already been explained, it might seem as if they were originally hollow or filled with some soft fleshy matter.

Lastly, in the horizontal section may be seen, as in *Caunopora*, the stelliform groups of vessels more or less scattered over each lamina, together with more or less transverse sections of them, according to their position, in the vertical section of *Stromatopora*—sometimes in distinct lines where the vessels have calcareous walls, at others as mere spaces in the rectilinear structure, when they may be so indistinct as to escape observation if not sought for carefully; while at other times they may not be present all, as stated in *Millepora alcicornis*, on account of their being concealed underneath the plane of the section, which may have just taken away the upper part of the layer bearing them, and not sufficient of the lower part to expose the following set. Again, in the vertical section there is often indication that a continuous vertical canal, to which I have before alluded, passed up through the whole of the stellate groups in that line, and, thus connecting them together, may have been developed from calicles successively formed on the surface, whereby a continuous canal would be kept up, as in the branch of *Madrepora abrotanoides* before cited; or the canal may be interrupted; or there may be no defined centre or indication of opening there as in *Stromatopora astroites*, Ros. (*op. cit.* Taf. ii. fig. 7); or there may be no stellate centre and the form may be merely dendritic, as in *S. Schmidtii*, Ros. (*ib.* Taf. iv. fig. 1), finally passing into the straggling form observed in *Millepora alcicornis*. Further, the branches of the stellate group may not be horizontal, but sloping all round, as when it is successively developed on the summit of a

mamillary process, *e. g.* in *Stromatopora polymorpha*. This is perhaps best seen in the vertical section, where according to the height of the elevation will be the slope of the vessels. But whatever form this vascularity may present, it cannot alter the function, which, as before stated, is that of the "proliferous membrane" or hydrophyton.

We now come to the calicles of *Stromatopora*; and as these are the last indications of the animal which formed it, and we have no "tubes" to aid us here as in *Caunopora*, it will be necessary to give close attention to this part of the subject if the chief object of this communication is to be realized.

I would here premise that, after Dr. Murie had, with his usual desire to sacrifice every thing to truth, however and by whomsoever elicited, shown me Prof. Nicholson's American specimens of *Stromatopora*, which being as they were found (that is, presenting their natural surfaces much better than might have previously been expected after the contingencies to which they must have been exposed for so many ages since they formed the cœnenchyma of living animals), my general impression was that these surfaces were more nearly allied to *Hydractinia echinata* than to *Millepora alcicornis*; and this I find to be confirmed by Prof. Nicholson's following description of his *Stromatopora granulata* (Ann. 1873, xii. p. 94), viz.:—"It forms thin crusts, often occupying very extensive surfaces (3×2 ft. $\times \frac{1}{2}$ in.). Composed of concentric laminæ, about ten in the space of a line, separated by interspaces which are minutely broken up into cells by numerous delicate vertical rods. Surface regularly undulating, often raised into chimney-like or conical elevations, which, however, are never perforated. The entire surface is covered with a fine miliary granulation." To which is added (Ann. 1874, vol. xiii. p. 10), "the pores consist of minute close-set perforations in a delicate calcareous membrane or surface-layer."

I examined several specimens of this species, viz. *S. granulata*, collected by Prof. Nicholson, at Dr. Murie's, and observed that the "conical elevations" were essentially like those of *Hydractinia echinata*; while in one specimen, where a part of the superficial layer had been taken off, and the vessels of the *Stromatopora* thus exposed, the latter presented the usual stellate appearance instead of the straggling form in *Hydractinia echinata* and *H. arborescens* (Ann. 1878, vol. i. p. 298, pl. xvii. fig. 1).

Again, Baron Rosen's representations of *S. Ungerni* (Taf. ix. figs. 5 & 6) and *S. dentata* (Taf. x. figs. 1 & 3), which were similar forms to *S. granulata*, Nich., are, in the matter of the conical elevations on the surface still re-

maining on the layers internally where the latter have been separated or are surmounted by hollow spaces, almost identical with what I have figured of *Hydractinia echinata*, *H. calcarea*, and the fossil species *H. pliocena* respectively (Ann. 1877, vol. xix. pl. viii. figs. 1, 4, and 9, *c*, *d*).

So that I am quite prepared, under these circumstances, not only *not* to find the "tubes" in *Stromatopora*, as stated by Lonsdale, but to find in their stead indications of the existence of *minute* holes on the surface, as in the *Hydractiniæ*, where they do not exceed the 1-600th of an inch in diameter.

Hall has figured them in his *Stromatopora concentrica*, but unfortunately has not added the measurement ('Palæontology of New York,' 1847, vol. ii. p. 136, pl. 73. figs. 1 *b* and 1 *c*); and I have often seen what I take to be the same foramina, but only in one instance where it seems to admit of no doubt; and this was in a specimen of (to me) *S. concentrica*, which came from the interior of a *Beekite* found near Torbay, and now in the possession of Mr. Vicary, of Exeter, who kindly lent it to me for examination. The transformation of the *Stromatopora* here into silex has been attended by such a definition of structure that the indication of the original holes or calicles which contain the animals is particularly convincing in one part, where they are filled with transparent silex, presenting respectively a white or flocculent centre. They are situated between the points of the "rods" which appear on the surface, are all of the same size, and measure 1-180th inch in diameter, while the white portion in the centre is 1-360th inch in diameter, each of which exceeds in this respect the diameter of the holes of the calicles (that is, the holes which permit the exit of the polypites) in the recent species of *Hydractinia*.

Thus we appear to arrive at the nature of the animal of *Stromatopora*, the signification of the stelliform groups of vessels, and the successive development of the cœnenchyma through *Hydractinia*, *Millepora alcicornis*, and *Caunopora*.

The general form of the Stromatoporidæ would appear to have been indefinite; that is, like reef-corals generally, they grew over every thing with which they came into contact, transforming some things into their own structure, and simply enveloping others, after the manner of *Hydractinia*, progressing by successive lamination; so that, whether *weathering* as in *Caunopora* or as in *Stromatopora*, this was, as in corals, the most prominent feature of the mass,—sometimes thin, spreading, and incrusting (as in *S. granulata*, Nich.), at others more or less massive and erect (as in *Caunopora* and *Stromatopora concentrica*). The most symmetrical specimen of the latter kind that I have seen is in the possession of Mr. Vicary, of Exeter, and

came from the Devonian Limestone near Newton Abbot. It is composed of compact black-grey limestone, and in shape is like a large fir-cone, nine inches in diameter longitudinally, five inches in diameter transversely about the centre, and three inches in diameter transversely at the base, which is truncated where it has been broken off from its original attachment. Consisting of layers like the coats of an onion, which, where broken out, show that the cœnenchyma was composed of undulatory laminæ bearing all the typical characters in structure above assigned to *Stromatopora concentrica*, *but very fine*. Each layer presenting on its surface gentle subcircular elevations or nodules, more or less uniform in diameter, and set together more or less regularly in juxtaposition, but all covered uniformly with a minute miliary granulation, interspersed irregularly with small papillary elevations, after the manner of *Hydractinia*, and each nodule surmounted by a stelliform group of vessels like those of *Stromatopora*. In other specimens, again, these elevations are raised into mammiform processes, as in *S. polymorpha*, Goldf.; and I believe that there are also branched forms, wherein, of course, the stelliform groups of vessels coming from the summits of the mammæ or branches respectively, or in the vertical section of the mass (for this is always sure to occur when, by their lateral growth, they touch each other), cannot present that horizontality which is observed where the layers are more planiform. But as a description of these would lead into the department of palæontology (that is, into specific distinction), I shall only further add that, by reason of the undulatory growth of the surface in the Stromatoporidæ, and the union of the processes thus produced when they come into contact with each other to form the whole mass, a more or less gnarly structure like that of knotted wood is often presented in the interior, which would otherwise be unaccountable.

Of the contributions to our knowledge of the Stromatoporidæ, by far the most valuable that has been published is that of Baron Rosen in 1867, to which I have before alluded, lately brought to my notice through the kind consideration of Prof. Zittel, of Munich. To the text of 98 pages are added, besides woodcuts, 11 lithographic plates, whose figures are preeminent both for accuracy and artistic delineation, illustrating the following ten species, viz.:—*Stromatopora typica*, R.; *S. variolaris*, R.; *S. astroites*, R.; *S. elegans*, R.; *S. Schmidtii*, R.; *S. polymorpha*, Goldf.; *S. mammillata*, F. Schmidt; *S. regularis*, R.; *S. Ungerni*, R.; and *S. dentata*, R.

In the text, by woodcuts and description, Baron Rosen makes the same division in the minute structure of the cœnen-

chyma as I have done, viz. into "rundlichen Maschen," our curvilinear, and into "dreieckigen Maschen," our rectilinear fibre; but in comparing the Stromatoporidæ with the sponges, he evinces an actual knowledge of the former and only a borrowed one of the latter; while even if he had been right in his identification of the two, it would have been better if this had been based on an *actual* knowledge *of both*.

To one well acquainted with the structure of different kinds of Stromatoporidæ it becomes easy, from what I have before stated of their excellence, to identify the whole of his illustrations. Thus *S. Schmidtii*, Taf. iv. and v., from which he takes the character of his "rundlichen Maschen" (p. 7), is evidently a *Caunopora* which has afforded the character of our "curvilinear fibre," as may be seen from the presence of the vertical spaces or tubes delineated in fig. 2, Taf. v.; while *Stromatopora typica*, Taf. i. and Taf. ii. fig. 1, which has afforded the character of his "dreieckigen Maschen" (pp. 6 & 17), is equivalent in typical structure to what we have assigned to *S. concentrica*—that is, our "rectilinear fibre." *S. elegans*, R., Taf. iii. fig. 1, is evidently the "stag's horn" (vulg.) species of the Devonian Limestone, which, of all that I have seen, presents the most beautiful venation internally. But here again I must stop, as this kind of comparison leads to specific distinction, which I propose leaving to the palæontologist.

With reference, however, to the stelliform groups of vessels called by Rosen "Faserbüschel," and so comparatively overlooked by all preceding and subsequent observers, we find them beautifully delineated, of the natural size, in six specimens out of the ten which he has illustrated; and where they were not seen, as in *S. Ungerni* and *S. dentata*, he suggests (p. 45) that this might have been owing to the "petrifying process." It might, however, have been owing, as before instanced in *S. granulata* (also one of the incrusting species), to their being concealed beneath the superficial layer. Still enough appears, in this admirable "Inaugural Thesis" for his Doctorate, to show that so important a feature in the Stromatoporidæ did not escape the intelligent author's notice, while it strongly recalls to mind the equally admirable "Thesis" of Dr. Ch. Barrois on the "Embryologie de quelques Éponges de la Manche."

Since this paper was written (1st Sept. 1878), I have received from Prof. Nicholson and Dr. Murie a copy of their valuable paper "On the Minute Structure of *Stromatopora* and its Allies" (extracted from the 14th vol. of the Linn. Soc. Journal, Zoology). This welcome contribution to our knowledge of the *Stromatoporæ* enters so fully into every thing connected with the subject that I can hardly do more than refer to that part

which bears upon the humble object of my communication.

In the first place, I wish the typical form of *Stromatopora* given at p. 195 had been taken from Mr. Vicary's specimen obtained from the Devonian Limestone near Newton Abbot, instead of from the specimen from the Lower Silurian of Canada" represented in Dr. Dawson's 'Dawn of Life,' as the former is almost perfect, and the latter extremely imperfect and much weathered. (A short description of Mr. Vicary's specimen has already been given.) As for the statement in the *footnote* at the bottom of this page, viz. that I had identified *Stromatopora* with *Caunopora*, what I meant to be understood was that *Caunopora* was the species of *Stromatopora* to which I had all along alluded, and that the so-called "hexactinellid structure" I had found in *S. concentrica*, mihi. I agree *in toto* with the authors at p. 201, where they conclude that the "Stromatoporoids were originally calcareous in their composition," also (at p. 203) that the "radial pillars" (our vertical lines or rods) were "solid," as I have already stated. At p. 209, the "radiated water-canals" are the stelliform groups of canals or branched vessels of our "proliferous membrane," equivalent in part to the hydrophyton of Allman whose contents and surroundings I have shown to have probably been nucleated cells; and, at p. 210, I must consider the "vertical water-canals," where not calicular tubes, to have been the canals of Annelids, with which the *Stromatoporæ* were evidently infested, like *Millepora alcicornis*—which is equally a prey to the boring sponge *Cliona*, whose cavernous excavations, connected by little thread-like canals, often give the coral a lacunose structure. It is with pleasure that I see (p. 217) that the specific descriptions and arrangement are only "provisional," as it affords a prospect of still more valuable information coming from the same source; while I feel convinced that until authors, who can never see *all* the type specimens, have the opportunity of seeing good representations of *all* the well-marked typical species (not like *Stromatopora concentrica*, Goldf. &c.), the nomenclature and arrangement of the Stromatoporidæ will remain in confusion. Thus, as regards the former, we have a *Stromatopora mammillata*, F. Schmidt, of 1858, *apud* Rosen, and a *Stromatopora mammillata*, Nicholson, of 1878, pl. i. fig. 10; again, there are other species figured in Rosen which appear to me, who possess such from the Devonian Limestone, to be figured by Nicholson and Murie under different names, &c., and so on.

I cannot admit any one of the "grounds" (*a–e* inclusive, pp. 228, 229) urged by the authors against my view that *Parkeria* was allied to *Stromatopora*, for reasons already pub-

lished (Ann. 1877, vol. xix. p. 55 *et seq.*), as well as those given in this paper. The cœnenchyma of *Parkeria* I hold to have been calcareous, and therefore the presence in it of all siliceous material to have been subsidiary or foreign, as in *Stromatopora*, to say nothing of the hosts of microscopic foreign organisms that were enclosed within their structures respectively during growth.

Still the "Flamborough-Chalk Fossils" to which I have alluded (Ann. 1878, vol. i. pp. 413–415), I *now know* not to have been the coralla of Hydrozoa as then suspected, but to have been the skeletal structures of Lithistid sponges respectively, which Prof. Zittel told me he had found at Ahlten, in Hanover, so much better preserved that the spiculation in them was undeniably Lithistid. They had been called by Phillips "*Spongia*" generically, with appropriate specific names, and figured in his 'Geology of Yorkshire.' But by far the most beautiful representations were drawn and lithographed, under the direction of Mr. Ed. Charlesworth, for his London Geol. Journal under the name of *Rhizospongia polymorpha*. These, unfortunately, were never published; but Mr. Charlesworth, in kindly presenting me with a set of them a short time since, added that he had written an account of the fossil Sponges of the Yorkshire Chalk, which might be found in the Proceedings of the Yorkshire Phil. Soc. for 1855 (vol. i. p. 73, pl. 1), with one illustration. In the British Museum these fossils now appear under the generic name of *Eudea*, Römer.

I would also mention here that Prof. Zittel has kindly sent me some calcareous fossils, with microscopic specimens of their structures respectively, showing that they were composed of *fibre* charged with such characteristic triradiate spicules that I must *now* admit that heretofore there have been *calcareous* sponges which have become fossil, although, as Prof. Zittel will probably show in his forthcoming paper on them, they were of a different kind from any now living.

To return, however, to Messrs. Nicholson and Murie's delightful exposition of the Stromatoporidæ, it is pleasant to me, living close to the great focus of Devonian *Stromatoporæ*, to find, in the *footnote* at p. 230, the evidence of an eye-witness that "the Stromatoporoids of the Eifel limestone are in no respect fundamentally different from those of the Devonian of Devonshire and North America."

Lastly, the authors repeat their opinion that, under the circumstances, the Stromatoporidæ should be viewed as "a new section of the Calcareous Sponges, for which" they "propose the name of *Stromatoporoidea*."

But, considering that our conception of a sponge will not

allow of our identifying any *other* structure with it, I cannot admit that the animal which produced *Stromatopora*, whatever it may have been, can have been a Spongozoon of the present day or of any other period. If modified, it could not have been a Spongozoon! The minute branches of the vessels of *Stromatopora* inosculate to form the hydrophyton, while the minute branches of the vessels of the excretory canal-system of a Sponge commence in the ampullaceous sac (*Wimperkörbe*).

In the 'Annals' for July this year, Dr. Dawson, F.R.S. &c., shows himself, it is hoped, to be a much better geologist than a palæontologist; for throughout his "careful microscopic studies of *Stromatoporæ*" in 1878, he seems to have been entirely ignorant of what Baron Rosen had done in 1867, or he would surely have somewhere alluded to this remarkable contribution to our knowledge of the Stromatoporidæ.

With such an omission, his failing to find the affinities of *Millepora alcicornis* to *Stromatopora* pointed out by "Mr. Carter" is not surprising to me.

To what "typical *Stromatoporæ*" of Hall, Nicholson, and Winchell, Dr. Dawson alludes when it is implied, from the statement in his 4th paragraph, "that the stelliform or radiating canals do not occur in the common species of *Stromatopora*," I am ignorant; for in all those to which I have alluded as having been brought from America they are present; and Hall's *Stromatopora constellata*, as may be seen from the illustration (*op. cit.* p. 324, pl. 72), seems to have been so named from their presence. It is true that Hall makes this a distinguishing character between his *S. constellata* and *S. concentrica*; but, from what has been above stated, he might have overlooked their representatives in the latter, as it is difficult to conceive how a *Stromatopora* could have been produced without such an organization.

Here, however, I would add that all the specimens of the so-called *Stromatopora concentrica* from the Upper Silurian system which I have had in my own possession and have seen in the museums of London, with the exception of one, have presented the structure of *S. concentrica* above detailed; but this one, which is the *type specimen* from which Lonsdale took his description and delineated his figure in Murchison's 'Silurian System' (1839), does not present the characters of *Stromatopora*, in so far as the surface, although covered with minute granulation, possesses no stelliform groups of vessels and nothing else besides the miliary granulation; while the vertical section, shows an amount of regularity in the laminæ which is seldom seen in the *Stromatoporæ*, together with a form of chamber or interstice square below and arched above, totally different from that of the *Stromatoporæ*, which,

on the other hand, is for the most part quadrangular and separated by distinct vertical rods, that may be followed continuously through a plurality of layers. Moreover the vertical section presents none of the transversely cut vessels of the stelliform groups, which are almost always more or less distinguishable in the vertical sections of *Stromatopora*. If this be the "common species of *Stromatopora*" to which Dr. Dawson alludes, then it is possible that he may be right. At the same time it is evidently not a "common species of *Stromatopora*," even if hereafter it should be found to be any species of *Stromatopora* at all. The specimen is now in the British Museum, and was kindly placed before me by Mr. H. Woodward.

After this, Dr. Dawson states that the "corallum of *Millepora*, on the contrary, has no concentric laminæ." How does this accord with the following description by Mr. Moseley of the living species he found at Tahiti, viz. "Layers more or less continuous occur in the more massive coralla, appearing in vertical sections as lines of calcareous matter running parallel to the surface of the corallum, and indicating successive stages of growth" (*op. et l. c.* p. 121)? Besides, the weathered end of any old piece of *Millepora alcicornis*, if cylindrical, will show this. Indeed it is difficult to conceive how it could be otherwise.

The allusion to my not being aware that "the stelliform or radiating canals do not occur in the common species of *Stromatopora*" has been answered; and the hint that my experience in these matters is "limited" is not worthy of a reply.

But when Dr. Dawson adds that it is "difficult to understand" the meaning of my observations on the so-called Eozoon in the paper under reference (Ann. 1878, vol. i. p. 310), I would here observe, by way of explanation, that when the structure of the crystalline stratified rocks called "*Eozoon canadense*" resembles organic remains as much as the play of glauconite in the trap-agates of Western India or any other part, it will be quite time enough to consider whether it is of organic or mineral origin. At present, all that I can state of it, after having examined many typical specimens, besides some in the rough state lately sent to the British Museum from Canada, is that it consists of a laminated structure, and that when it shall be found to present the other structural features of *Stromatopora* (to which *Eozoon* is *now* said to be allied) in addition to this lamination, which is as common in mineral as in organic structure, then, and then only, will I admit its organic origin.

Lastly, when Dr. Dawson offers "mail chippings" for microscopical examination, as if his own opinions had been settled

in this way, it puts me in mind of the late Sir Charles Napier in Sind, when I heard and saw him, in his little subaltern's tent, tear off his coat and throw it down in anger, observing to an officer who had come to report his arrival, "There, Sir, did you ever work in your life after this fashion?" meaning in his "shirt-sleeves."

How far the stelliform groups of vessels may always indicate a *Stromatopora* I am not able to state; but they are equally present on the surface of both *Ceriopora venosa*, Goldf. (Taf. xxxi. fig. 2, *a*, *b*), and *Cœnostroma*, Winchell, 1866 (Proc. Amer. Assoc.), as evidenced by the illustration of the former, and specimens of the latter in Prof. Nicholson's American collection, where he does not consider *Cœnostroma* generically different from *Stromatopora* (Nich. and Murie, *op. cit.* p. 210).

XXXVII.—*Studies on Fossil Sponges.*—II. *Lithistidæ.*

By Karl Alfred Zittel.

[Continued from p. 247.]

B. *Special part* *.

A. Rhizomorina.

Cnemidiastrum, Zittel.

Cnemidium p. p., *Achilleum* p. p., Goldf.
Cnemidium and *Cnemispongia*, Quenst.
Cupulospongia p. p., D'Orb.
Cnemiopelta, *Cnemipsechia*, *Pachypsechia*, ? *Ceriopelta*, and *Trachycinclis*, Pom. (non *Cnemidium*, D'Orb. & Pom.).

Sponge top- or skittle-shaped, cylindrical or cup-shaped, with a depressed central cavity, monozoic, rarely polyzoic. Thick wall traversed by numerous vertical radial fissures (furrows), which frequently fork once or several times exte-

* This portion of Dr. Zittel's memoir has been somewhat abridged. His statement of the sources from which he derived his specimens has been omitted; the species marked with an * are those of which he has examined the original types. He gives the following list of abbreviations employed:—

Court. Ép. foss.=Courtiller, A., "Éponges fossiles des sables du terrain crétacé supérieur des environs de Saumur," Ann. Soc. Linn. de Maine et Loire, 1861, vol. iv.

Etal. Leth. Br.=Etallon et Thurmann, "Lethæa Bruntrutana," Neue Denkschr. schw. naturf. Gesellsch. 1863, Bd. xix. & xx.

From. Intr.=Fromentel, E. de, "Introduction à l'étude des éponges fossiles," Mém. Soc. Linn. Norm. vol. xi. 1859.

Gein. Elbth.=Geinitz, "Das Elbthalgebirg in Sachsen," Paläontogr. Bd. xx.

Goldf.=Goldfuss und Münster, Petrefacta Germaniæ, Bd. i. 1826–1833.